Journal of Biomechanics 84 (2019) 1–3

Contents lists available at ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech

In memoriam – John D. Currey, 1932–2018

The biomechanics community is deeply saddened by the loss of Professor John Donald Currey. John was born in Scunthorpe (UK) on 9th August 1932 and shortly after, he moved with his parents to Pickwick in Wiltshire, where he spent his childhood, completing his school education at St. Edward's school in Oxford. He went on to complete his National Service obligations in the Artillery, after which he went up to read Zoology at Brasenose College, Oxford, graduating with a first in Zoology in 1956.

Following graduation, John joined the Southern Harvester whaling ship team, on a trip to the Antarctic serving as a second temporary whaling inspector. His job was to monitor the size, species, and numbers of the catch and insuring the protection of nursing mothers. He returned to Oxford to work as a Departmental Demonstrator in the Zoology Department and went on to study for his doctorate, which was published in 1961. Three years later, John moved to the newly formed University of York, where he helped set up the Biology Department. John has been interested in hard tissue ever since, particularly bone, throughout his academic career. He did however spend some years examining the population genetics of the snail Cepaea. Biomechanics was an unexpected career change: He often remembered his exact position in the room with his hand on the door handle, when the engineer with whom he had been consulting

https://doi.org/10.1016/j.jbiomech.2019.01.028

said, ‘Why don’t you test it?’. He had up to that moment, being a zoologist, not thought of mechanical testing.

John met Jillian, his wife, in 1958 and they married in 1960, and they had a girl and two boys. At the end of the sixties John, Jillian and their three children spent a year in Cleveland, Ohio, where John did research at the Veterans Administration Hospital and Case Western Reserve University. At the end of the year they drove across the whole United States from coast to coast camping, ending up in Martha’s Vineyard where John conducted research at the Lobster Hatchery. Upon returning in 1970, John joined the University of York staff as a Professor. He spent many years teaching and researching bone in all its manifestations, eventually taking on the duties of Head of Department and Deputy Vice Chancellor. He worked in the Department of Biology at York until his official retirement in 1999 where he remained as an Emeritus Professor.

Since his retirement, John actively continued to pursue his many research interests, focusing on biomechanics and the mechanical properties of mineralized tissues. He collaborated with numerous colleagues throughout the world and continued to attend conferences and examine PhD students. Over the years, John published more than a hundred papers - his first was published in 1959 on “Differences in the tensile strength of bone of different histological types” until his last co-authorship, published in 2017 on “Importance of the variable periodontal ligament geometry for whole tooth mechanical function: A validated numerical study”.

One of his major research interests was microcracking and its relevance for the toughness of bone. John explored the existence of the minute cracks by confocal microscopy following loading of bone specimens. In his own words: “When bone starts to break thousands of little microcracks form. These microcracks are positioned sensibly in relation to the histological structure of the bone, but we don’t know where they form in relation to the ultrastructure. Typically when microcracks form they only reach a few microns in length before they come to a halt. The big question is, what brings them to a halt?”.

Another topic John pursued was bone aging. He produced, “by hard experimentation” as he often recalled, a large database of the mechanical properties of different kinds of bones and other mineralized tissues. For his contributions to biomechanics, The European Society of Biomechanics awarded John the Huiskes Medal for Biomechanics in 2013.

He summarized his main findings in 1984 in a book entitled “The Mechanical Adaptations of Bones”, and later in his well-known book “Bones – Structure and Mechanics”. He was a long-time member of the editorial board of the “Journal of Biomechanics”, and more recently of the “Journal of the Mechanical Behaviour of Biomedical Materials”. He stayed very active scientifically after his retirement, both publishing (50 papers since retirement) and reviewing more than 40 papers each year. He remained an engaged member of the Journal of Biomechanics board even during his retirement. Indeed, he saw his role as a reviewer as part of his duty, to give back to the scientific community.

As well as John’s commitment to getting the science right, he was a brilliant and charismatic teacher, excellent at personal communication and always willing to consult on research and act as a mentor. He helped to shape many careers with his boundless enthusiasm and helpful advice. He was an art and poetry enthusiast and a life-long hill walker. He combined his love of maps and running in the sport of orienteering and represented his country a few times in international competitions.

John died peacefully in his sleep on 18th December 2018. He leaves a wife Jillian, daughter Louise, sons Guy and Nicholas and three grandchildren.

John summarized his research interests, in his’s own, special style:

John D. Currey: My scientific work (2003)

I remember, more than 25 years ago at a party, saying to a girl that my real ambition was to find out what happens when a bone breaks. That is still what I am after. We know a great deal about the stresses and strains that you have to impose on bones in order to make them break, but we still have very little idea of what goes on in a nitty-gritty way as cracks start to form, coalesce, and become dangerous. Bone has a quite extraordinarily intimate relationship between its mineral (hydroxyapatite) and its main protein (collagen). The apatite crystals are plate-like and very thin (3° nm or so), and insert themselves between the collagen molecules to produce an architecture that is still unclear. When bone starts to break thousands of little microcracks form. These microcracks are positioned sensibly in relation to the histological structure of the bone, but we don’t know where they form in relation to the ultrastructure. Typically when microcracks form they only reach a few microns in length before they come to a halt. The big question is, what brings them to a halt? (Microcracks in themselves can be a good thing, because they absorb energy as they form, and the ability to form microcracks makes the bone tough. There is a corresponding disadvantage that they make the bone less stiff.)

My major interest recently is in this microcracking. The literature is full of reference to ‘microcracks’, but what people have meant by this is cracks 100° μm or so long. Such long cracks are already on their way to being dangerous. We found multitudes of cracks that were 5 °μm or so long, and which are much more interesting because they absorb huge amounts of energy as they form. For several years I have been going to conferences saying ‘Look folks, these are the important cracks, get a confocal and look!’ Solid resistance at first, for some reason, but people are at last coming round to the idea, and the literature is growing. I have been pursuing these microcracks, seeing, for instance, how there are less of them in brittle bone, less of them in bone that has been irradiated, and we are getting some idea about how they grow and multiply.

I also work on other areas of bone mechanics.

(1) What is the effect of aging, disease, and treatment on the mechanical properties of bone? I am interested in how bone gets less tough with age, and what causes this - is it a change in the stability of the collagen (answer probably yes) or is it a change in the mineral, or is it that the bone becomes deranged or changed at a somewhat higher level (the histological). The detailed way this bone breaks up in old versus young, osteoporotic and osteoarthritic pathologies is giving us a clearer understanding of the cause of the incidence of fractures in various pathological states.

(2) What is the range of the mechanical properties of bone and how are they adapted to the functional requirements of the animal? I have produced, by hard experimentation over the years, and am adding to, a large database of the mechanical properties of various bones. We are finding some very extreme properties, some of which can be clearly seen to be adaptive, others less so. I am also concerned with whether the more usual differences one finds in ‘ordinary’ bones are adaptive. I have also compared fatigue and other properties of highly mineralised bone with that of similarly mineralised mother of pearl, and found that mother of pearl is far superior (presumably because mother of pearl is designed to be highly mineralised, bone isn’t.

(3) I have had a blinding glimpse of the obvious and, using my large data set, looked at the relationship between the stiffness of the bone and its bending strength. There is an extremely tight proportional relationship, which no-one has really commented on before. This sounds like a piece of Ho

Hum, but is actually very important, because it shows that the bending strength of bone is determined by its yield stress (still with me?). The extent to which it is not the yield stress, tells us other related things about the fracture process in bending. This kind of thing is rather well known to mechanical engineers in other materials, but its presence and significance in bone has not been described before. I am looking at similar effects in tension and find very interesting differences.

(4) Nanoindentation is a technique that allows one to examine the stiffness of very small areas of bone. We are using this technique to look at how the stiffness changes between the inside of Haversian systems and outside, and with orientation, and with age.

(5) People who have been moaning at me occasionally about not producing a second edition of my book may or may not be pleased to know that it is now published: 'Bones: structure and mechanics' (2002) Princeton University Press. Those who are brave enough to read it (everybody should buy it) should know that there is an error in Table 3.2. The values 141 12 (10) and 156 7.9 (6) should both be moved one column to the right. People who care about these things would have worked this out for themselves, I think. Sorry. No doubt there are other errors!

Claudia Fleck
Fachgebiet Werkstofftechnik – Materials Engineering Department, Technische Universität Berlin, Germany
E-mail address: claudia.fleck@tu-berlin.de